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The Specific Surface Area Values for Iowa Tills

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Specific surface area is a property used by earth scientists to estimate the proportion of expandable clay minerals in soils. In this study, specific surface area method is shown to compare favorably with standard clay mineralogical techniques in determining gross differences in expandable clay mineral content in tills. The results of over 100 measurements on till samples from Iowa indicate undifferentiated pre-Illinoian tills from southern and southwestern Iowa have the highest specific surface area values of Iowa tills (ranging from nearly 100 to greater than 150 m^2/g) and Wisconsinan Dows Formation tills have the lowest average specific surface area values (approximately 50 to 80 m^2/g. Pre-Illinoian tills from eastern Iowa have significantly lower average specific surface area values than undifferentiated pre-Illinoian tills collected from southern and southwestern Iowa. Specific surface area determinations proved useful in distinguishing between pre-Illinoian till units at the formation level in eastern Iowa. The use of this property at the formation and sub-formation level in Wisconsinan tills is less diagnostic. Limited specific surface data exist for Illinoian tills, which appear to have clay mineral compositions intermediate between those of undifferentiated pre-Illinoian tills from southern and southwestern Iowa and Wisconsinan tills.
INDEX DESCRIPTORS: Pleistocene stratigraphy, pre-Illinoian till, Wisconsinan till, surface area, clay mineralogy.

Recent studies of Pleistocene stratigraphy in Iowa indicate that clay mineralogy is a valuable tool in characterizing and stratigraphically differentiating till deposits (Hallberg, 1980a,b; Kemmis et al., 1981). Studies using the "semi-quantitative" analysis of clay mineralogy (Hallberg et al., 1978), show that the proportion of expandable layer silicates in tills is useful in differentiating between till units, particularly at the formation level. Although the "semi-quantitative" method is useful, it relies upon careful sample preparation and calculation techique. Results from different laboratories are often different.

Specific surface area is an easily measured property. It is used by earth scientists to estimate the proportion of expandable layer silicates in soils and is defined as the surface area per unit mass of soil. It is predominantly a function of clay mineralogy. Non-expanding layer silicates, such as kaolinite and illite, have external surfaces only. These clays tend to have specific surface areas which range from 10-70 m^2/g. Expanding layer silicates, such as smectites and vermiculite, have both internal and external surfaces, and may have specific surface areas ranging up to 810 m^2/g (Carter et al., 1986). Because of large differences in surface area between the non-expanding and expanding layer silicates, clay mineralogy is usually the dominant factor in determining the total surface area. However, differences in specific surface area are also dependent upon clay content. If two samples have the same proportion of expandable clays but significant differences in clay content, the sample with a higher percentage of clay will have a higher specific surface area. Specific surface area can also be influenced by organic matter content and the type and nature of secondary iron and manganese oxides. These latter two factors are probably negligible for the till weathering zones sampled in this study.

Although specific surface area determinations have been routinely made on soils, few if any determinations have been made on tills below the soil solum. The objectives of this study are twofold: 1) to compare the clay mineralogy of select till samples (determined by the semi-quantitative method) with the specific surface area determinations, and 2) to present the results of specific surface area measurements of various till stratigraphic units in Iowa.

METHODS

Till samples were collected primarily from quarries located throughout Iowa (Figure 1). Additional samples had been collected by Dr. R.A. Stewart (pers. comm.) and Baker (1985). Grain size analysis was made of eight till samples using sieve and hydrometer techniques (Stewart and Gedlinske, 1986), and duplicate samples were sent to the Iowa Department of Natural Resources Geological Survey Bureau for semi-quantitative analysis of the clay mineralogy using the method of Hallberg et al. (1978).

The specific surface area was determined using a method similar to those of Heilman et al. (1955) and Cihacek and Bremner (1979). The samples were sieved, and approximately 1.1 gram of the finer than 60 mesh (0.25 mm) fraction was weighed into preweighed aluminum weighing tins. The samples dried to a constant weight over phosphorus pentoxide (P_2O_5) in a desiccator, then were treated with approximately 2 ml of ethylene glycol monoethyl ether (EGME) to form a slurry. The slurry was placed over calcium chloride ($CaCl_2$) in a desiccator and allowed to equilibrate for 15-30 minutes after which the air in the desiccator was evacuated. The samples were then periodically weighed until a constant weight was attained. After each weighing the samples were returned to the desiccator and the air evacuated. The specific surface area was calculated by dividing the grams of adsorbate retained per gram of sample by 0.000286 m^2/g (Carter et al., 1986).

At least two specific surface area determinations were made on each sample. If differences in the specific surface area were greater than approximately 5-10 m^2/g, the sample analysis was repeated.

RESULTS

Comparison of Standard Clay Mineraological Techniques and Specific Surface Area

A comparison was made between the specific surface area and the semi-quantitative clay mineralogy on eight pre-Illinoian till samples from southwest Iowa (Fig. 1). The textural, mineralogical, and specific surface area properties of the samples are shown in Table 1.

The clay mineral composition determined using the semi-quantitative technique indicates that montmorillonite dominates the clay fraction in all the samples, and that illite and kaolinite are also present (Fig. 2). The relative proportion of expandable clays between the samples can be compared based on the relative size of the peaks. Expandable clays make up the largest proportion of the till clay minerals in all the samples (48 to 71%) with a higher proportion of expandable clays in some samples (e.g. Mt. Etna, Crescent). The illite percentage remain relatively constant in all the samples, whereas the amount of kaolinite + chlorite is inversely proportional to the amount of expandable clay minerals.

The relationship between the semi-quantitative determination of clay mineralogy and specific surface area is presented in Fig. 3. The graph shows that the proportion of expandable clay minerals is highly correlated with the specific surface values. The coefficient of correlation between the two variables is 0.91.

Specific surface area is not strongly correlated to differences in texture. The correlation coefficient between clay content and specific surface area is 0.41.

Specific Surface Area of Iowa Tills

The results of over 100 specific surface area measurements on till samples are summarized in Table 2. The location of the sample sites

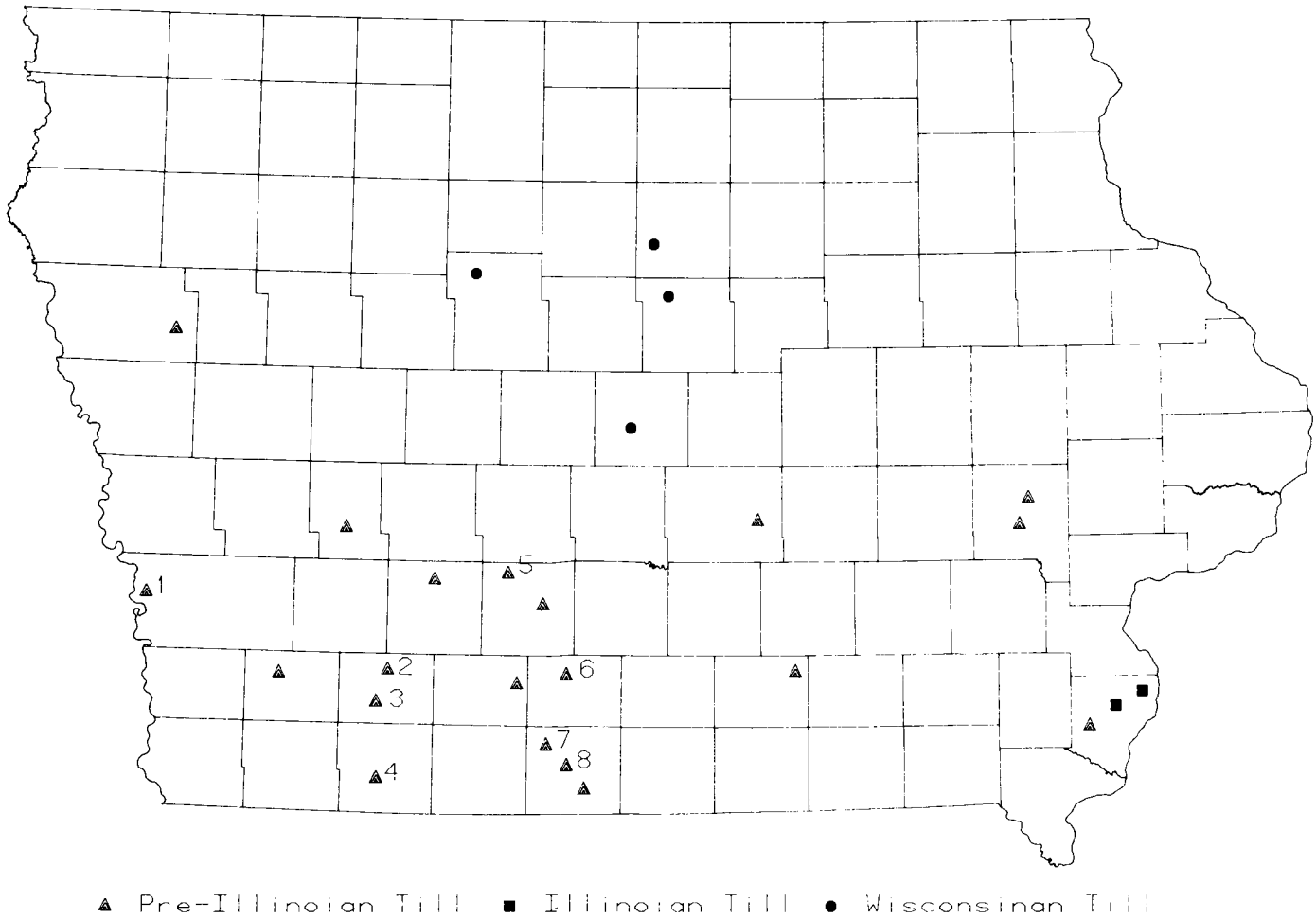

Fig. 1. Location of samples collected for study. Numbers correspond to selected till samples shown on Table 1.

and the stratigraphy of the samples are shown in Fig. 1.

The majority of analyses were made on Wisconsinan till and on undifferentiated pre-Illinoian till of southern and southwestern Iowa. In general, undifferentiated pre-Illinoian tills of southern and southwestern Iowa have 30 to 50 percent higher specific surface areas than Dows Formation till (Table 2). Specific surface area values from the pre-Illinoian Alburnett and Wolf Creek Formations of eastern Iowa are generally comparable to the Dows Formation data; values for Wisconsinan Tazewell till are similar to those of undifferentiated pre-Illinoian till from southern and southwestern Iowa.

The specific surface area of Dows Formation sediments, in general, fall within a 60 to 75 m^2/g range. The Morgan Member of the formation has the lowest specific surface area values of the Wisconsinan tills (Fig. 4). The Alden Member of the Dows Formation exhibits more variability than the Morgan Member, but the values are generally concentrated in the 50 to 70 m^2/g range. The specific surface area

Table 1. Texture, specific surface area, and clay mineralogy of selected till samples. Locations of numbered samples shown on Fig. 1.

Quarry Location	Granulometric Analysis			Specific Surface Area (m^2/gr)	Clay Mineralogy		
	Sand %	Silt %	Clay %		Ex. %	Ill. %	K.+C.%
1. Crescent	27	49	24	125	61	18	21
2. Mt. Etna	16	53	31	202	71	22	7
3. Corning	28	53	19	151	58	18	24
4. Bedford	28	46	26	146	58	19	23
5. Earlham	31	47	22	96	53	18	29
6. Osceola	29	43	28	103	50	18	32
7. Grand River	37	44	19	105	48	18	34
8. Decatur City	32	41	27	106	48	19	33

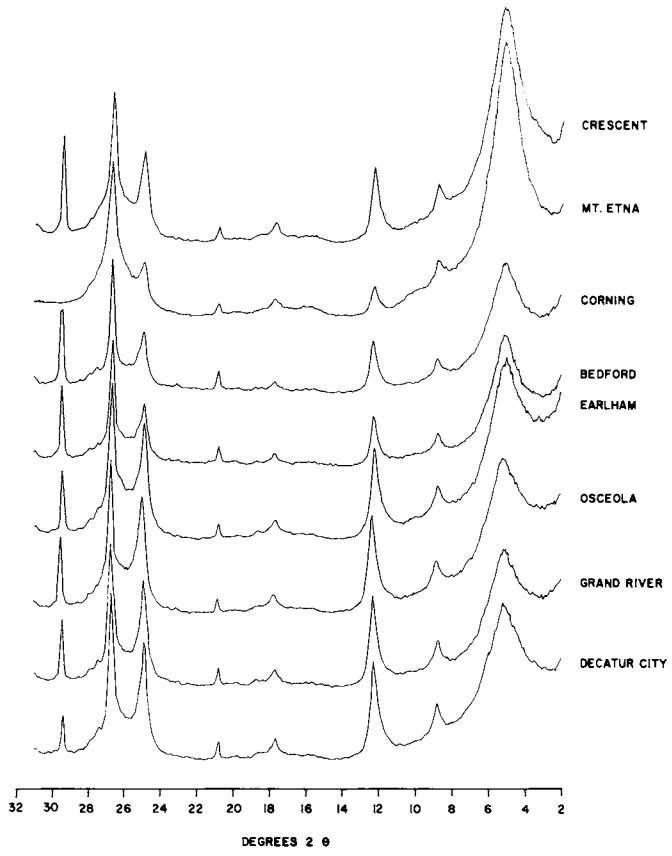

Fig. 2. X-ray diffractograms for glycolated till samples.

values for Morgan Member deposits are generally lower than those of the Alden Member, although there is considerable overlap.

The specific surface area of Tazewell till samples is the most variable (s.d. = 27.6), ranging from a low of 80 m^2/g to a high of 151 m^2/g. These values are significantly higher than those of the Dows Formation.

Table 2. Summary of specific surface area values.

Formation	*n*	Mean	Std. Dev.	Range
Wisconsinan (total)	54	79	24.6	49-151
Dows Formation	42	70	14.2	49-109
Morgan Member	12	61	8.7	49-74
Alden Member	30	74	14.4	51-109
Tazewell	12	111	27.6	80-151
Illinoian	4	81	10.2	72-90
Kellerville	2	72		72
Glasford	2	90		88-91
Pre-Illinoian (total)	55	114	36.7	50-202
Wolf Creek	6	88	14.1	75-110
Alburnett	6	63	9.2	50-77
Undifferentiated	43	134	27.3	96-202

There is limited specific surface data for the Illinoian tills of southeastern Iowa. Available data indicate these tills have a range of values intermediate to the Wisconsinan and pre-Illinoian tills.

A large range of specific surface values is associated with the pre-Illinoian till samples (Table 2, Fig. 5). Differences in specific surface between eastern Iowa pre-Illinoian formations are observable; Alburnett till values are concentrated in the 50 to 70 m^2/g range and the Wolf Creek samples generally fall in the 70 to 100 m^2/g range (Fig. 5). These eastern Iowa samples have distinctly lower surface areas than the stratigraphically undifferentiated samples from southern and southwestern Iowa (Fig. 1), which exhibit the highest average surface area value (134 m^2/g) and the most variability (s.d. = 27.3).

Other Analyses

Measurements were made on materials related to the till samples for comparative purposes. The large difference in surface area between expanding and non-expanding layer silicates was verified by the analyses of kaolinite and bentonite. The kaolinite samples had a value of 32 m^2/g whereas the bentonite exhibited a specific surface of 538m^2/g. Pebbles of Cretaceous shale from late Wisconsinan till at Whatoff's borrow pit in Story County had specific surface area values ranging from 177 to 185 m^2/g.

DISCUSSION

The strong correlation between the percent expandable clays and the corresponding specific surface area values indicates that there is

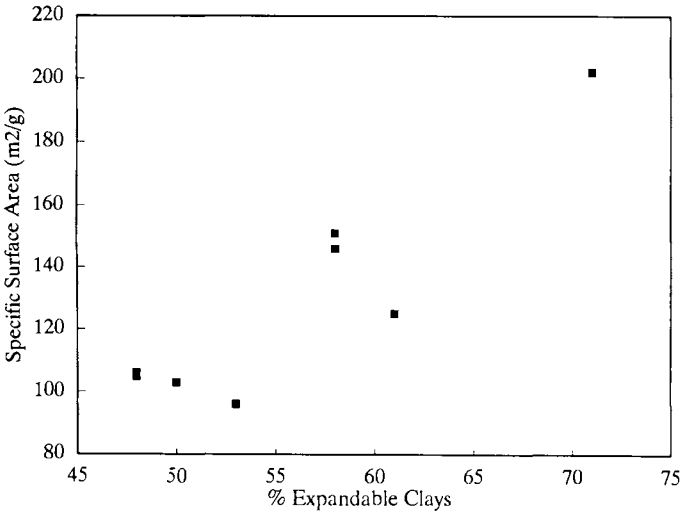

Fig. 3. Correlation of specific surface area values and expandable clay percentage.

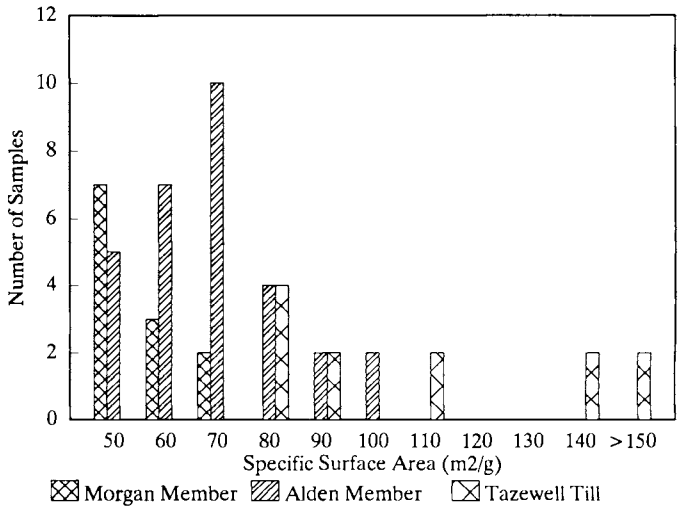

Fig. 4. Histogram of specific surface area values for Wisconsinan tills.

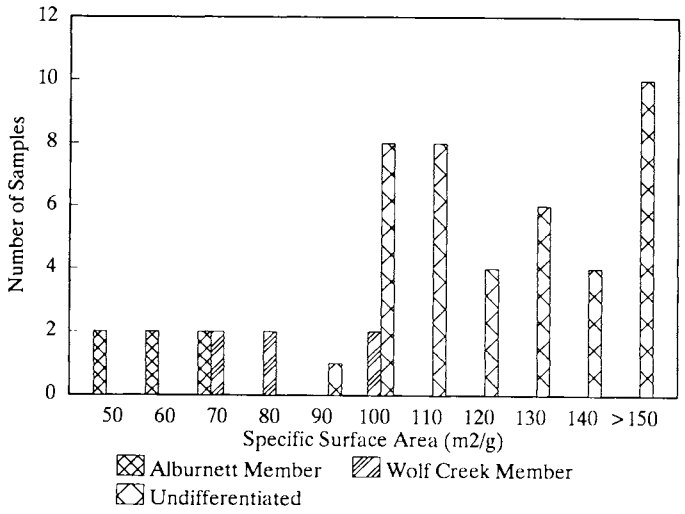

Fig. 5. Histogram of specific surface area values for pre-Illinoian tills.

good agreement between these two techniques in determining gross differences in expandable clay content. Gross differences in the amount of expandable clays present are often sufficient in characterizing and distinguishing between samples. Considering the textural homogeneity within Iowa basal till formations (Kemmis, 1981; Kemmis et al., 1981; Hallberg, 1980a; 1980b) differences in specific surface area among till stratigraphic units should closely approximate differences in expandable clay mineralogy. The results of specific surface area analyses on a variety of Iowa tills indicate that this technique is useful for distinguishing till units, particularly at the formation level.

Wisconsinan vs. Pre-Illinoian Tills

Wisconsinan tills have lower specific surface areas than pre-Illinoian till, particularly undifferentiated pre-Illinoian tills from southern and southwestern Iowa. Dows Formation tills have nearly half the specific surface area of undifferentiated pre-Illinoian tills from southern and southwestern Iowa (Table 2). This relationship is not as apparent with pre-Illinoian tills from eastern Iowa (Wolf Creek and Alburnett Formations), nor as obvious with Wisconsinan Tazewell till. Overlap in specific surface area values exists between Dows Formation tills and eastern Iowa pre-Illinoian tills and between Tazewell till and undifferentiated pre-Illinoian tills from southern and southwestern Iowa. Reasons for the overlap are not conclusively known, although they may be partially attributed to differences in texture between till units.

Pre-Illinoian Till

Specific surface area determinations may prove extremely useful for stratigraphic differentiation at the formation level where large textural differences are seldom observed in basal tills. Pre-Illinoian till from eastern Iowa has been primarily differentiated on the basis of clay mineralogy; the younger Wolf Creek Formation averages 62.1% expandable clay minerals, whereas the Alburnett Formation averages 42.9% (Hallberg, 1908b). Data from this study indicate that the difference in expandable clay proportion between the two formations is reflected in the specific surface values. Alburnett till values are concentrated in the 50 to 70 m^2/g and the Wolf Creek samples fall in the 70 to 100 m^2/g range. Although more data are needed to verify these ranges, specific surface area data may be an alternative to standard clay mineralogical analyses in deciphering pre-Illinoian till stratigraphy in eastern Iowa.

The specific surface area of undifferentiated pre-Illinoian till from southern and southwest Iowa is considerably higher than for pre-Illinoian tills from eastern Iowa. This appears to indicate significant differences in the expandable clay content of pre-Illinoian tills between these two regions; however, additional stratigraphic and textural information on the undifferentiated samples must be known before any conclusions regarding these differences can be made.

Wisconsinan Till

The reason for the large variability in surface area associated with the Tazewell till is unclear, although the limited data do indicate that the Tazewell till does have, on the average, higher specific surface values than Dows Formation tills. Perhaps the high average specific surface area and the large variability of surface area values distinguish this unit from the younger Wisconsinan tills.

Using specific surface for stratigraphic distinctions at the subformation level in Wisconsinan tills is more problematic. Because the Dows Formation exhibits little variation in clay mineralogy, the relative textural heterogeneity of the Morgan Member is likely to produce greater variability and slightly lower specific surface area values compared to the Alden Member.

CONCLUSIONS

The specific surface area method compares favorably with standard clay mineralogical techniques in determining gross differences in expandable clay content. Each method offers a standardized basis on which to compare clay mineralogical differences between samples. Because specific surface area analyses are primarily a function of expandable clay percentage and clay content, this technique offers little in the way of determining the overall clay mineralogy of a sample. However, the ease in which this method is performed and the results interpreted and quantified make specific surface a potentially useful and diagnostic property in stratigraphically discriminating between till units at the formation level.

The results of over 100 specific surface measurements on Iowa till samples suggest:

1. In general, undifferentiated pre-Illinoian till from southern and southwestern Iowa has the highest specific surface areas of Iowa tills. Values range from approximately 100 to greater than 150 m^2/g. The values are higher than for pre-Illinoian tills of the Wolf Creek and Alburnett Formations of eastern Iowa.
2. The difference in expandable clay percentage between the Alburnett and Wolf Creek Formations is reflected in the specific surface values. Although more data are needed to verify the ranges, the surface area values of the Alburnett Formation are concentrated in the 50 to 70 m^2/g range, and the Wolf Creek Formation are found in the 70 to 100 m^2/g range.
3. Wisconsinan Dows Formation tills exhibit the lowest average surface areas of Iowa tills, concentrated in the 50 to 80 m^2/g range. Little variation in the clay mineralogy of the Dows Formation generates overlap in specific surface area values between the Alden and Morgan Members.
4. Specific surface area values from Wisconsinan Tazewell till exhibit large variability and higher average values than Dows Formation tills.
5. Limited data for Illinoian tills of southeastern Iowa indicate these tills have an intermediate composition between the undifferentiated pre-Illinoian tills of southern and southwestern Iowa and Wisconsinan Dows Formation tills.

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